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TEST OF NACA 66,2-116, a = 0.6 AIRFOIL SECTION FITTED WITH PRESSURE BALANCE AND SLOTTED FLAPS FOR THE WING OF THE XP-63 AIRPLANE

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WASHINGTON

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MEMORANDUM REPORT

for

Army Air Forces, Materiel Command

TEST OF NACA 66,2-116, a = 0.6 AIRFOIL SECTION FITTED WITH PRESSURE BALANCED AND SLOTTED FLAPS FOR THE WING OF THE XP-63 AIRPLANE

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INTRODUCTION

At the request of the Army Air Forces, Materiel Command, tests have been made in the Langley two-dimensional low-turbulence pressure tunnel of a model of the NACA 66,2-116, a = 0.6 airfoil section representing the root section of the wing for the XP-63 airplane.

The data presented in this report consist of the following:

(a) Lift, drag, and flap hinge-moment characteristics for the internal balanced flap.

(b) Lift, drag, and flap hinge-moment characteristics for the "modified" internal balance flap.

(c) Lift and drag characteristics for the slotted flap.

The model was of 24-inch chord (c_W), built of wood with dural slot cover plates for the flap. All flaps were equipped with pressure orifices.

METHOD[1]

Lift and drag measurements were made by methods described in reference 1.

The flap hinge moments were obtained from pressure-distribution measurements by integrating the normal and chordwise pressure-distribution diagrams, the pressures being plotted against the orifice projections on the flap chord line and a line perpendicular to the chord line.

TESTS AND RESULTS

Internal balance flap ($c_f = 0.1667c_w$).- Lift, drag, and pressure distributions over the flap, fully sealed, were made on the model at various angles of attack (α) for flap deflections (δ_f) of 0°, 10°, 20°, 30°, 40°, and 50°. The gaps between the flaps and slot covers in the original condition were measured and found to be $0.0013c_w$ - top and $0.0052c_w$ - bottom. The results of these tests are presented in figures 1, 2, 7, and 8.

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[1] At the time this report was originally published, some of the corrections required for reducing the test data to free-air conditions had not been determined. The values of section lift coefficient c_l (figs. 3 to 8 and figs. 11 to 16) should be corrected by the following equation

$$c_{l\,(corrected)} = 0.965c_l + K$$

where the values of K are obtained from the following table:

Flap deflection δ_f (deg)	K
0	0.003
10	.006
15	.009
20	.012
30	.018
40	.030
45	.027
50	.026

The tests were repeated for flap deflections of 15° and 45° with the gap on the upper surface enlarged to $0.0052c_w$, the lower remaining the same. These results are presented in figures 3 and 4, and tables I and II.

The tests were again repeated for flap deflections of 0°, 10°, and 45° with the same gaps and the pressure seal (curtain) removed. These results are presented in figures 5 and 6, and table I.

"Modified" internal balance flap ($c_f = 0.1667c_w$).- Lift, drag, and pressure distributions over the flap, fully sealed, were made at various angles of attack for flap deflections of 0°, 10°, 20°, 30°, 40°, and 50°. The results of these tests are presented in figures 7, 8, 9, and 10.

Slotted flap ($c_f = 0.2505c_w$).- Lift and drag data were obtained at flap deflections of 0°, 15°, and 45° with the slot cover plates in three different slot conditions designated in the sketches on figures 11, 12, and 13 as conditions 1, 2, and 3, respectively. The flap hinge point was located in three different positions for each slot condition, except condition 3, and designated as upper, middle, and bottom (figs. 11, 12, and 13). The results of these tests are presented in figures 11, 12, 13, 14, 15, and 16.

DISCUSSION

Internal balance flap.- The section hinge-moment coefficients in figure 1 for the original gaps and in the fully sealed condition in table I for the $0.0052c_w$ gaps, do not include the hinge moments from the pressure difference across the sealing curtain. Figure 2 and table II respectively give the pressure-coefficient difference across the curtain from which it is possible to calculate the balancing effect of the curtain.

Comparing the fully sealed condition with $0.0052c_w$ gap (table I) with the original gap configuration (fig. 1), it can be seen that for a flap deflection of 15°, the hinge moments for the $0.0052c_w$ gaps were larger than for the original gaps; however, for a flap deflection of 45° there was very little change in the hinge moments. This is probably due to the fact that at the small flap deflections the sensitivity of the flap to small internal pressure changes is better than at large flap deflections where the flap is stalled.

Table I shows the hinge moment for the flap at an angle of attack of 3.0° to be larger for the sealed condition than for the no-seal condition. This is due to the internal pressure which is in such a direction as to increase the hinge moment rather than decrease it, as shown in table II. This pressure reversal is possibly due to the combination of a peak pressure on the flap at the hinge and the large gaps. A comparison of the hinge moments for the two conditions in table I at a flap deflection of 45° where the flap is stalled shows the internal balance to be counterbalancing about one-third of the unbalance moment. Although the gaps are different, a further comparison at a flap deflection of 10° between figure 1 and the no-seal condition in table I shows the internal balance to be more effective when the flap is not stalled.

It can be seen from comparing figures 3 and 5 with the original configuration for the internal balance flap in figure 7 that the maximum lift is little affected either by small changes in the gap between the slot covers and flap, or by removing the sealing curtain. Comparing figure 3 with figure 5 it can be seen that the lifts for the sealed and no-seal conditions, at a flap deflection of 0° with $0.0052c_w$ gaps, are about the same; however, for the no-seal condition at a flap deflection of 45° the maximum lift is slightly higher than for the sealed condition.

Comparing the fully sealed configuration having $0.0052c_w$ gaps (fig. 4) with the original configuration for the internal balance flap (fig. 8) shows that at a flap deflection of 15° in the low-drag range, a small decrease in profile drag resulted from increasing the gap on the upper surface to $0.0052c_w$. Comparing the no-seal condition (fig. 6) with the original internal balance flap (fig. 8) shows that at a flap deflection of 10° a marked increase in the drag resulted from flow through the gaps.

"Modified" internal balance flap.- The section hinge-moment coefficients for the "modified" flap (fig. 9) do not include the hinge moments from the pressure difference across the sealing curtain. Figure 10 gives the pressure-coefficient difference across the sealing curtain from which it is possible to calculate the balancing effect of the curtain. Comparing the section hinge-moment coefficients for the "modified" flap (fig. 9) with the original configuration for the internal balance flap (fig. 1) shows the internal balance flap to have slightly lower hinge moments.

The lift characteristics of the model with either the internal balance flap or the "modified" flap are about the same (fig. 7).

The profile drag at a flap deflection of 10° with the "modified" flap is slightly higher than for the internal balance flap in the low-drag range, as shown in figure 8.

Slotted flap.- A comparison of figures 11, 12, and 13 shows that the highest maximum lift coefficients are obtained in each condition with the flap deflected 45° in the bottom hinge location. With this hinge location, condition 1 gave a maximum lift coefficient of about 2.52 (fig. 11). Removal of part of the bottom slot cover plate, condition 3, resulted in only a slight increase in the maximum lift coefficient (fig. 13). In condition 2, the bottom slot cover plate removed and the slot faired smooth, a value of about 2.76 was obtained (fig. 12). Lift characteristics at $\delta_f = 0^\circ$ were practically the same for all slot conditions.

Drag coefficients were obtained for all three slot conditions at hinge locations and flap deflections, shown in figures 14, 15, and 16. The values of the drag coefficients were uncertain in many of the conditions tested, possibly due to localized spanwise separation or spanwise flow in the slot. An attempt was made in condition 2, $\delta_f = 0^\circ$, to prevent this spanwise flow by putting several thin dams in the bottom of the slot on either side of the region where measurements were taken, but it is doubtful that this stopped all the cross flow. The uncertain parts of the drag curves are drawn with dash lines (figs. 14, 15, and 16). These should be considered for qualitative purposes only. Figures 14, 15, and 16 show that a marked increase in minimum drag occurs in condition 2 at $\delta_f = 0^\circ$, because of the open slot on the lower surface. Even with the slot partially closed in condition 3, there was still a slight increase in drag.

It is apparent for good flap characteristics that the slotted flap be designed to include a door to cover the slot in the retracted position for low drag and to deflect about the bottom hinge location with the slot open for maximum lift.

Comparison of flaps.- Although higher maximum lift coefficients are obtainable with the slotted flap tested than with the plain flap, comparatively little gain is shown by the slotted flap unless a low flap hinge point is used. A door is also required for the slotted flap if high maximum lift coefficients, flap deflected, and low-drag coefficients, flap neutral, are both to be realized. It also appears that the plain flap offers some advantages over the slotted flap tested in extending the low-drag range to higher lift coefficients, when the gap is fully sealed (fig. 4).

Even if the mechanical complications of the slotted flap with door and low hinge location are acceptable, some danger exists of inducing tip stalling of the wing by the use of a powerful flap. This effect has been shown to occur on tests of a model of a somewhat similar airplane in the NACA 19-foot pressure tunnel. It is therefore recommended, that the plain flap, fully sealed, be used for the XP-63 airplane if the maximum lift coefficients obtained with this flap are acceptable.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 23, 1942.

REFERENCE

1. Jacobs, Eastman N., Abbott, Ira H., and Davidson, Milton: Preliminary Low-Drag-Airfoil and Flap Data from Tests at Large Reynolds Numbers and Low Turbulence. NACA ACR, March 1942.

TABLE I

Hinge-Moment Coefficients on 0.1667 c_w Internal Balance Flap on a NACA 66,2-116 a = 0.6 Airfoil Section at a Reynolds Number of 6,000,000

Angle of Attack (α)		0°	2.0°	3.0°	4.1°	8.1°	12.2°	16.2°	-4.1°
Model Configuration		Section hinge-moment coefficient, c_h							
Fully sealed	$\delta_f = 0°$			-0.025					
0.0052 c_w gap-top and	$\delta_f = 15°$	-0.112	-0.117		-0.122	-0.145	-0.155		-0.053
bottom (*)	$\delta_f = 45°$	-0.348	-0.354		-0.347	-0.336	-0.312	-0.498	-0.345
No seal	$\delta_f = 0°$	0.005		-0.013	-0.018	-0.050	-0.105	-0.132	+0.020
0.0052 c_w gap-	$\delta_f = 10°$	-0.102		-0.149	-0.145	-0.162	-0.190	-0.229	-0.081
top and bottom	$\delta_f = 45°$	-0.488		-0.495	-0.487	-0.470	-0.466		-0.484

* Hinge-moments from curtain not included.

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TABLE II

Pressure Difference Across Curtain for a NACA 66,2-116 a = 0.6 Airfoil Section

With an Internal Balance 0.1667 c_w flap, 0.0052 c_w gap-top and bottom

fully sealed; Reynolds number of 6,000,000

Angle of Attack (α)		0°	2.0°	3.0°	4.1°	8.1°	12.2°	16.2°	-4.1°
Model Configuration		Pressure coefficient difference across curtain, $S_U - S_L$							
Fully sealed	$\delta_f = 0^\circ$			-0.009					
0.0052 c_w gap-	$\delta_f = 15^\circ$	0.671	0.634		0.625	0.625	0.662		0.752
top and bottom	$\delta_f = 45^\circ$	1.196	1.223		1.251	1.251	1.196	1.776	1.006

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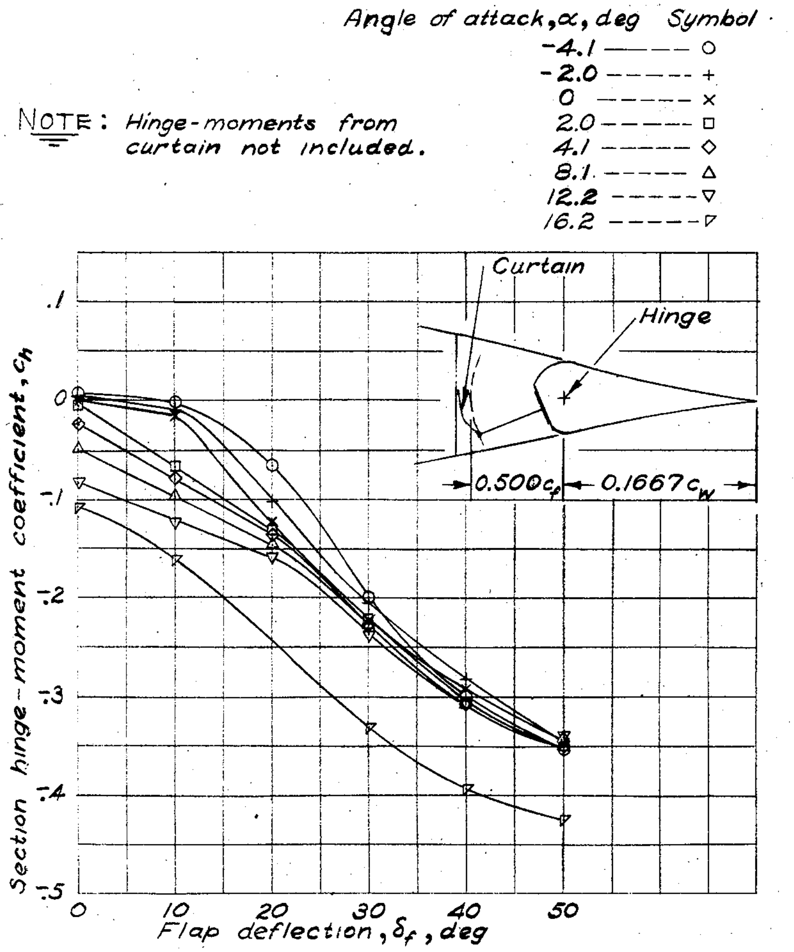

Figure 1 — Hinge-moment versus flap deflection for a NACA 66,2-116 a=0.6 with an internal balance 0.1667 c_w flap, gap-0.0013 c_w top and 0.0052 c_w bottom, fully sealed; Reynolds number of 6,000,000.

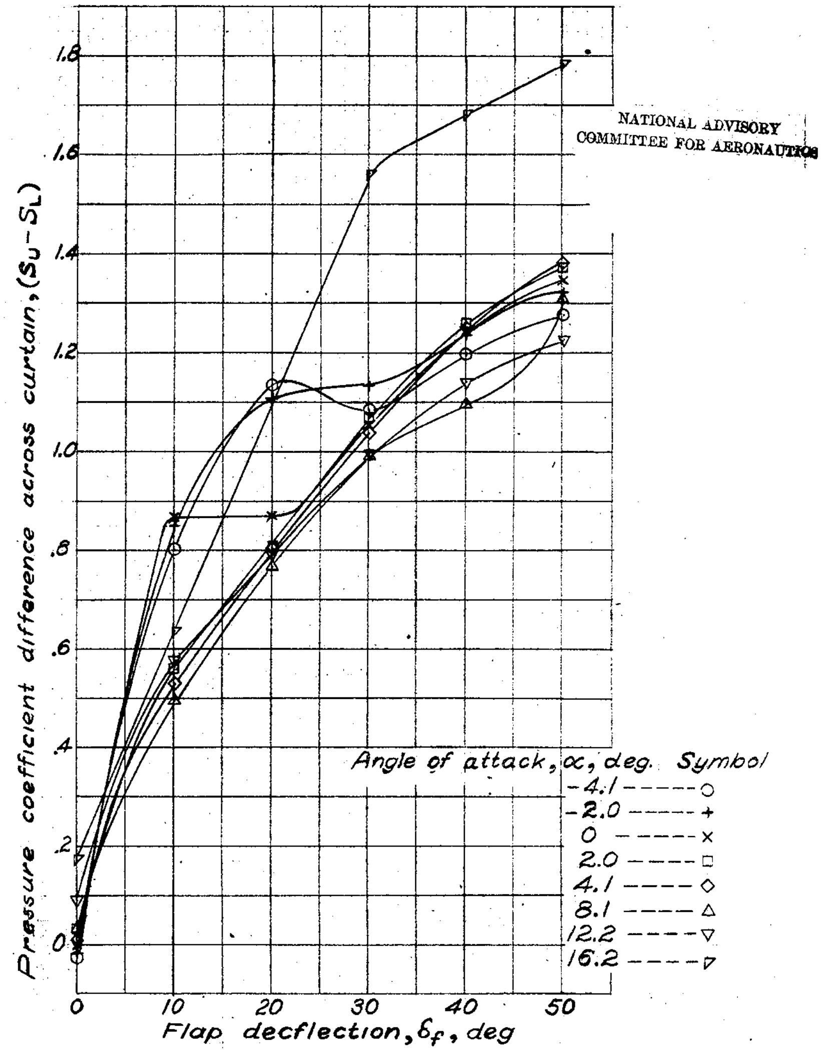

Figure 2 — Pressure difference across curtain for a NACA 66,2-116 a=0.6 with an internal balance 0.1667 c_w flap, gap - 0.0013 c_w top and 0.0052 c_w bottom, fully sealed; Reynolds number of 6,000,000.

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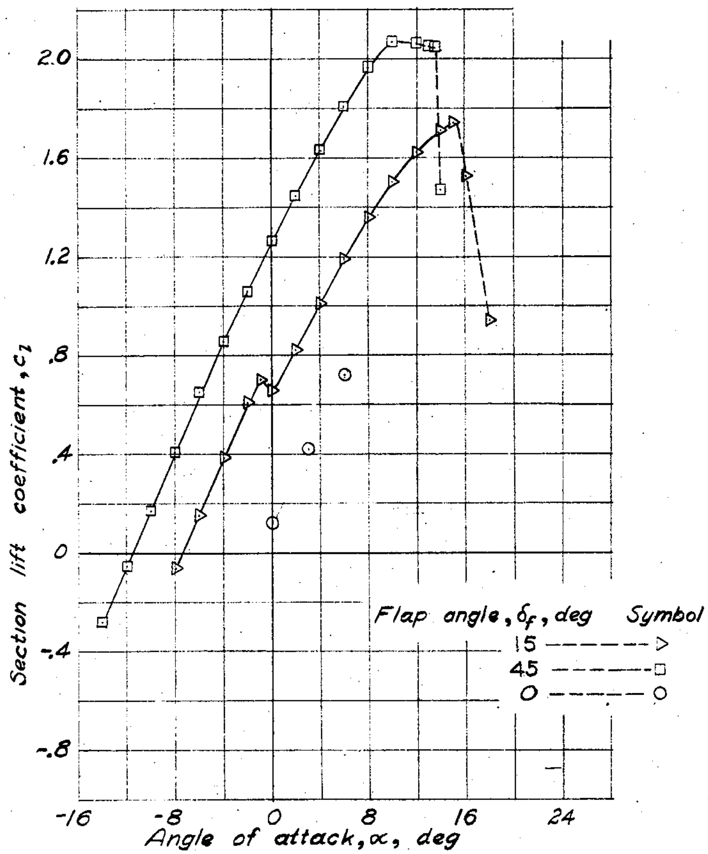

Figure 3 — Lift versus angle of attack for a NACA 66,2-116 a=0.6 with an internal balance 0.1667 c_w flap, 0.0052 c_w gap-top and bottom, fully sealed; Reynolds number of 6,000,000.

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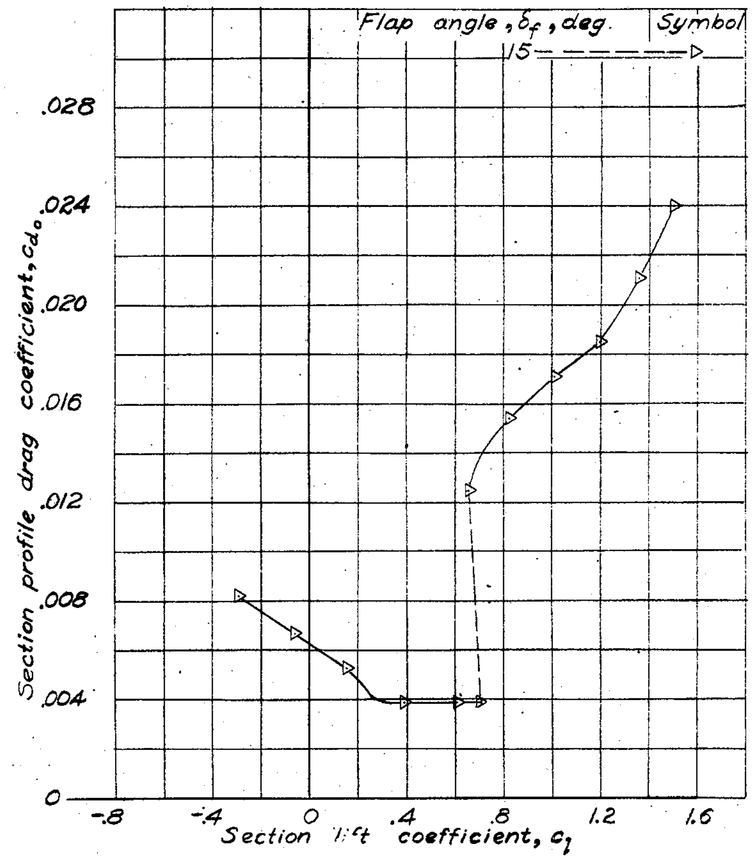

Figure 4 — Lift versus drag for a NACA 66,2-116 a=0.6 with an internal balance 0.1667 c_w flap, 0.0052 c_w gap-top and bottom, fully sealed; Reynolds number of 6,000,000.

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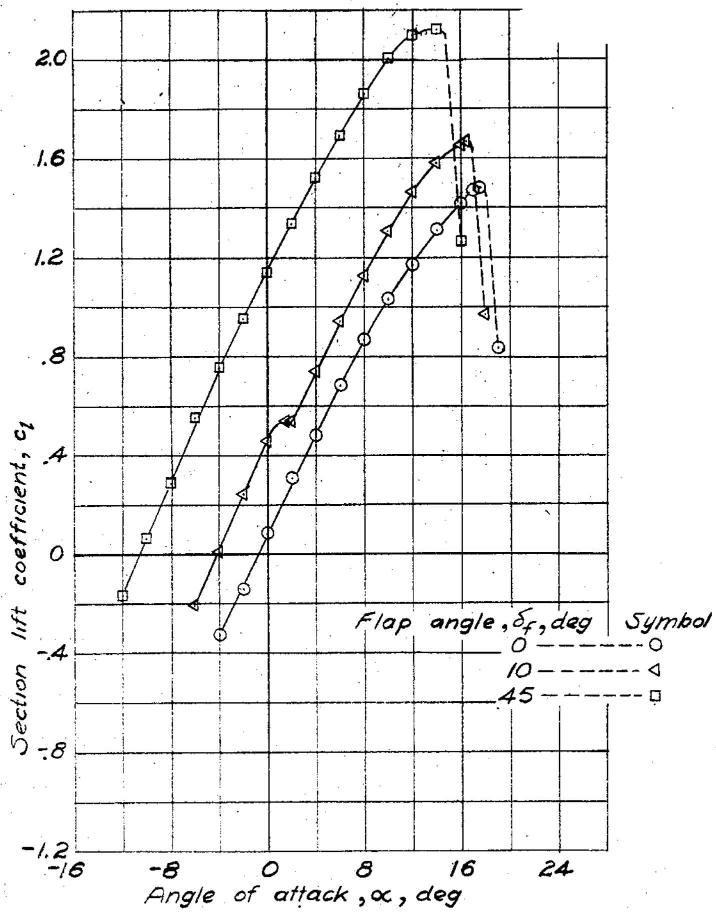

Figure 5 — Lift versus angle of attack for a NACA 66,2-116 a=0.6 with an internal balance 0.1667 c_w flap, 0.0052 c_w gap-top and bottom, pressure seal removed; Reynolds number of 6,000,000.

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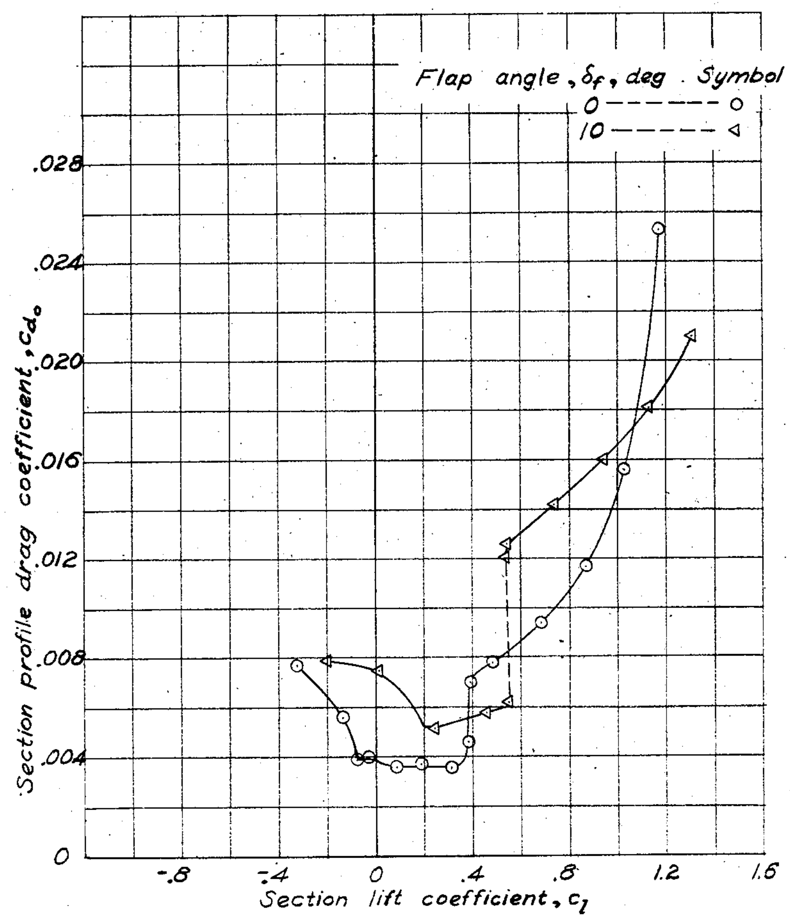

Figure 6 — Lift versus drag for a NACA 66,2-116 a=0.6 with an internal balance 0.1667 c_w flap, 0.0052 c_w gap-top and bottom, pressure seal removed; Reynolds number of 6,000,000.

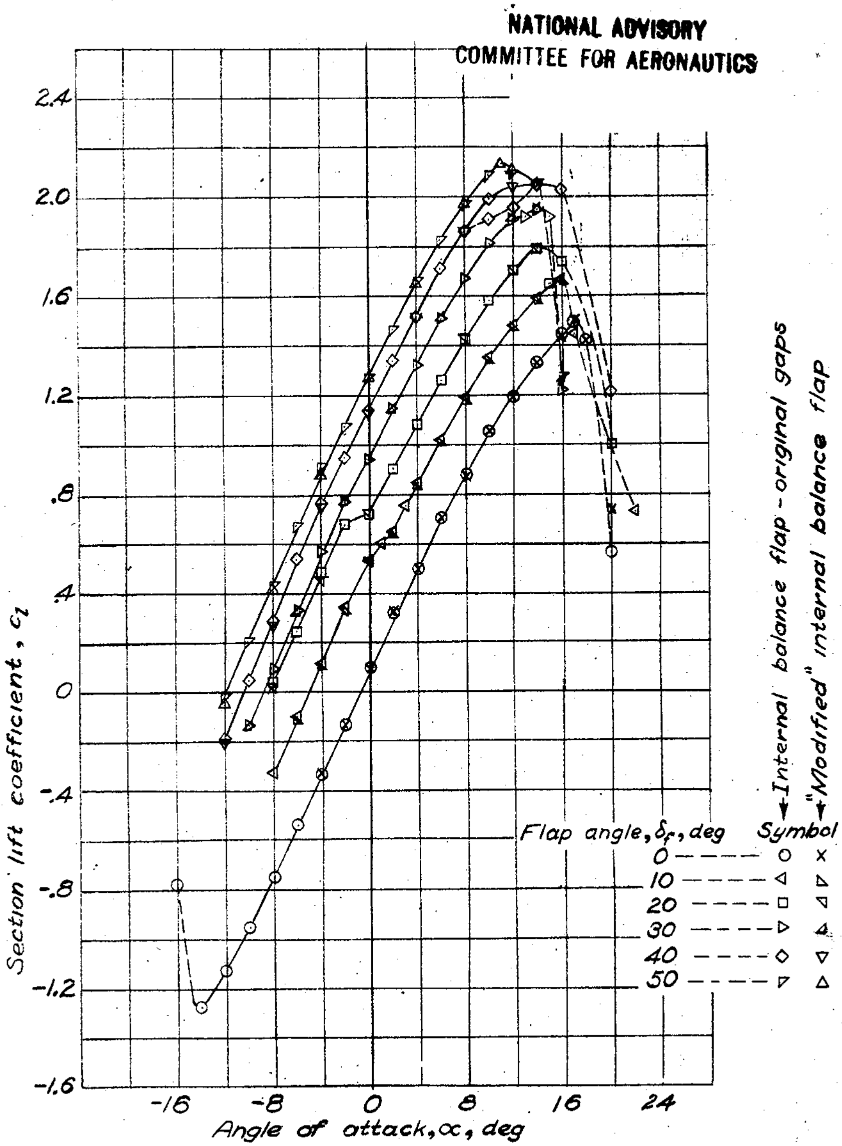

Figure 7 — Lift versus angle of attack for a NACA 66,2-116, a=0.6 with a pressure sealed 0.1667c_w flap at a Reynolds number of 6,000,000.

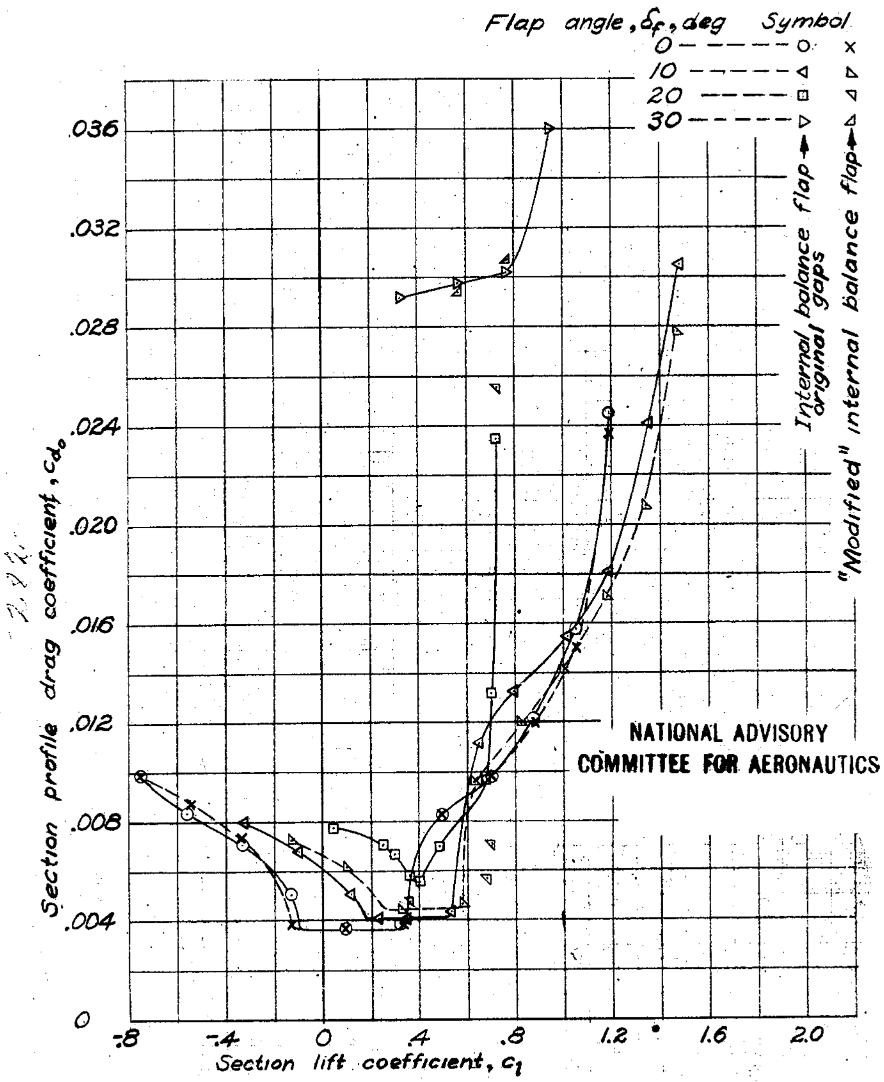

Figure 8 — Lift versus drag for a NACA 66,2-116, a=0.6 with a pressure sealed 0.1667c_w flap at a Reynolds number of 6,000,000.

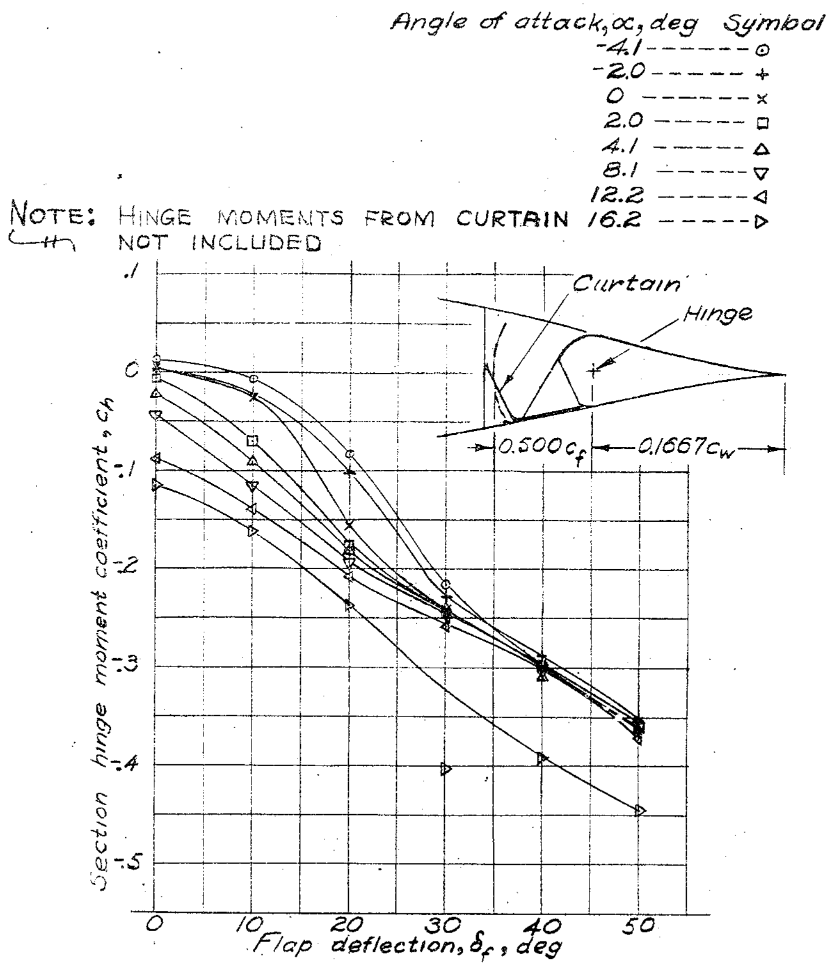

Figure 9 — Hinge moments versus flap deflection for a NACA 66,2-116, a=0.6 with a 0.1667c_w "Modified" internal balance flap, fully sealed; at a Reynolds number of 6,000,000.

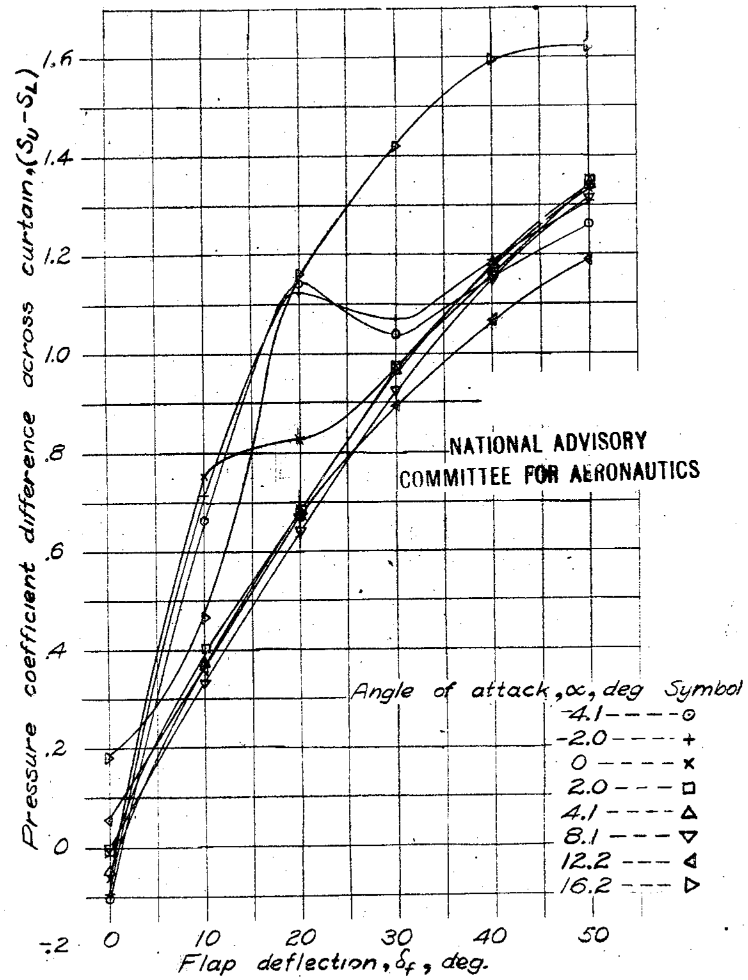

Figure 10 — Pressure difference across curtain for a NACA 66,2-116, a=0.6 with a 0.1667c_w "Modified" internal balance flap, fully sealed; at a Reynolds number of 6,000,000.

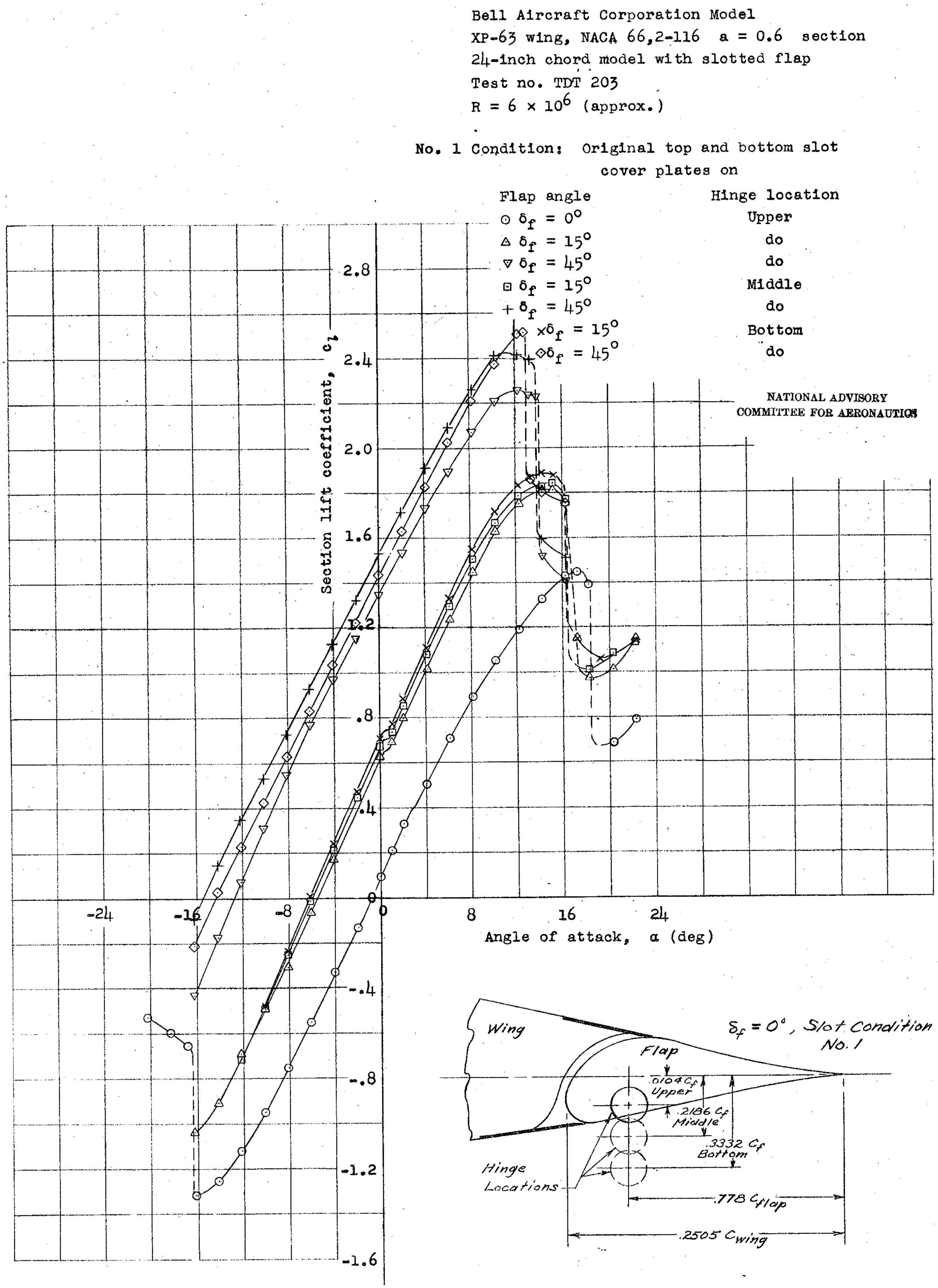

Figure 11.- Lift characteristics with original top and bottom slot cover plates on.

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Bell Aircraft Corporation Model
XP-63 wing, NACA 66,2-116 a = 0.6
section
24-inch chord model with slotted flap
Test no. TDT 203
R = 6 × 10^6 (approx.)

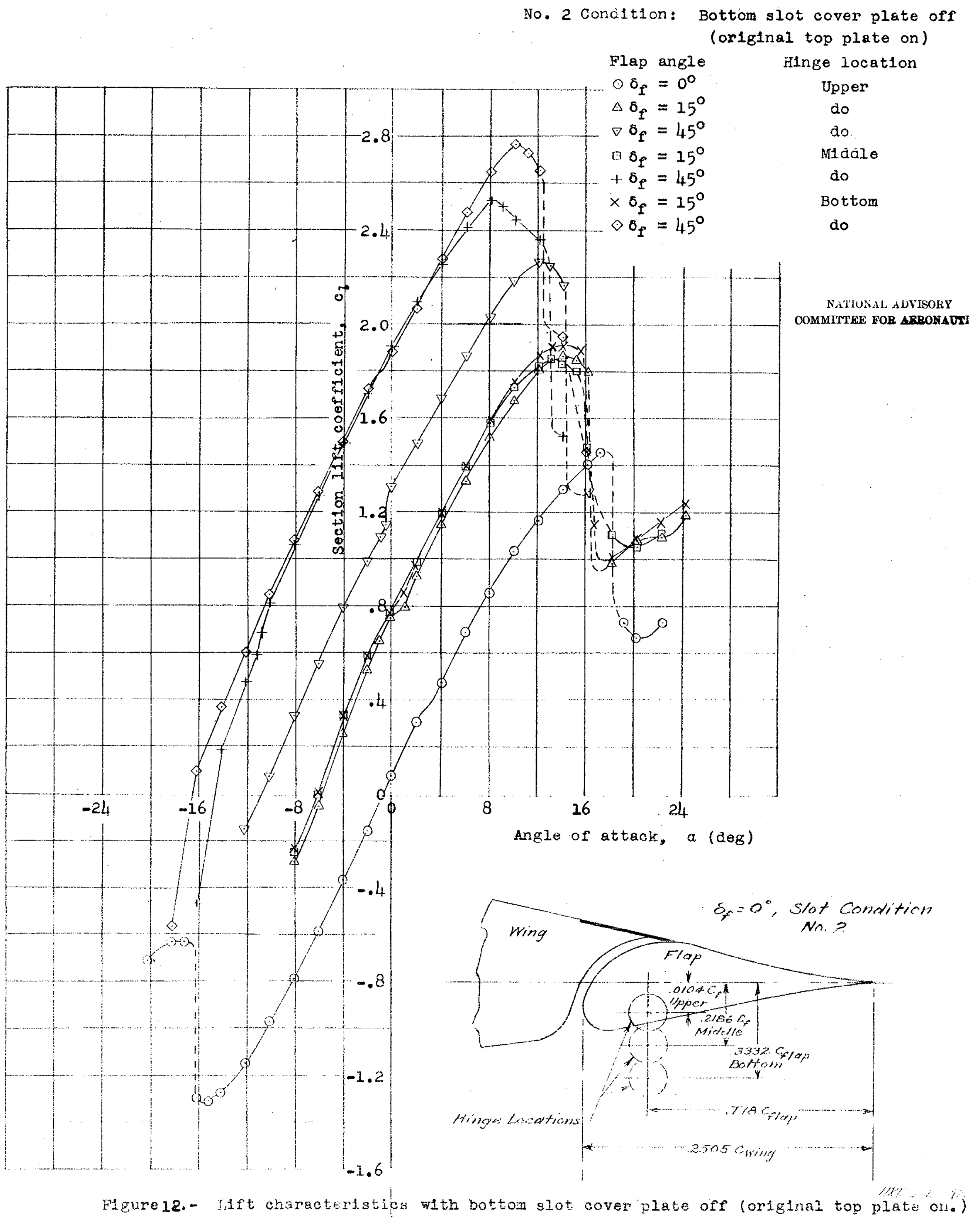

Figure 12.- Lift characteristics with bottom slot cover plate off (original top plate on.)

Bell Aircraft Corporation Model
XP-63 wing, NACA 66,2-116 a = 0.6
section
24-inch chord model with slotted flap
Test no. TDT 203
$R = 6 \times 10^6$ (approx.)

No. 3 Condition: Partial bottom slot cover plate on (5/8-inch shorter than original). Original top cover plate on.

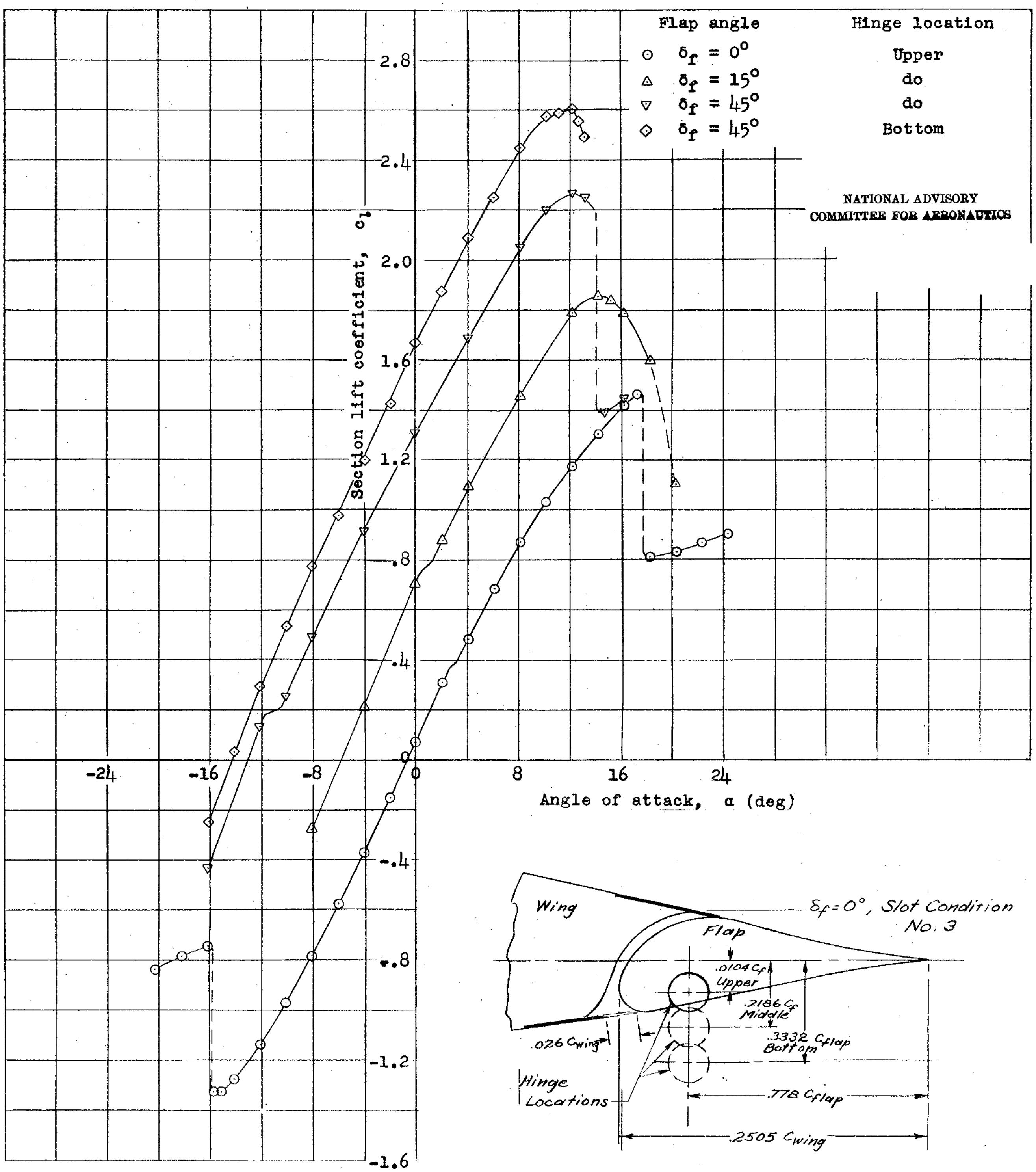

Figure 13.- Lift characteristics with partial bottom cover plate on (original top plate on).

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Bell Aircraft Corporation Model
XP-63 wing, NACA 66,2-116 a = 0.6 section
24-inch chord model with slotted flap
Test no. TDT 203
$R = 6 \times 10^6$ (approx.)

No. 1 Condition: Original top and bottom slot cover plates on

Flap angle	Hinge location
⊙ $\delta_f = 0°$	Upper
△ $\delta_f = 15°$	do
⊡ $\delta_f = 15°$	Middle
× $\delta_f = 15°$	Bottom

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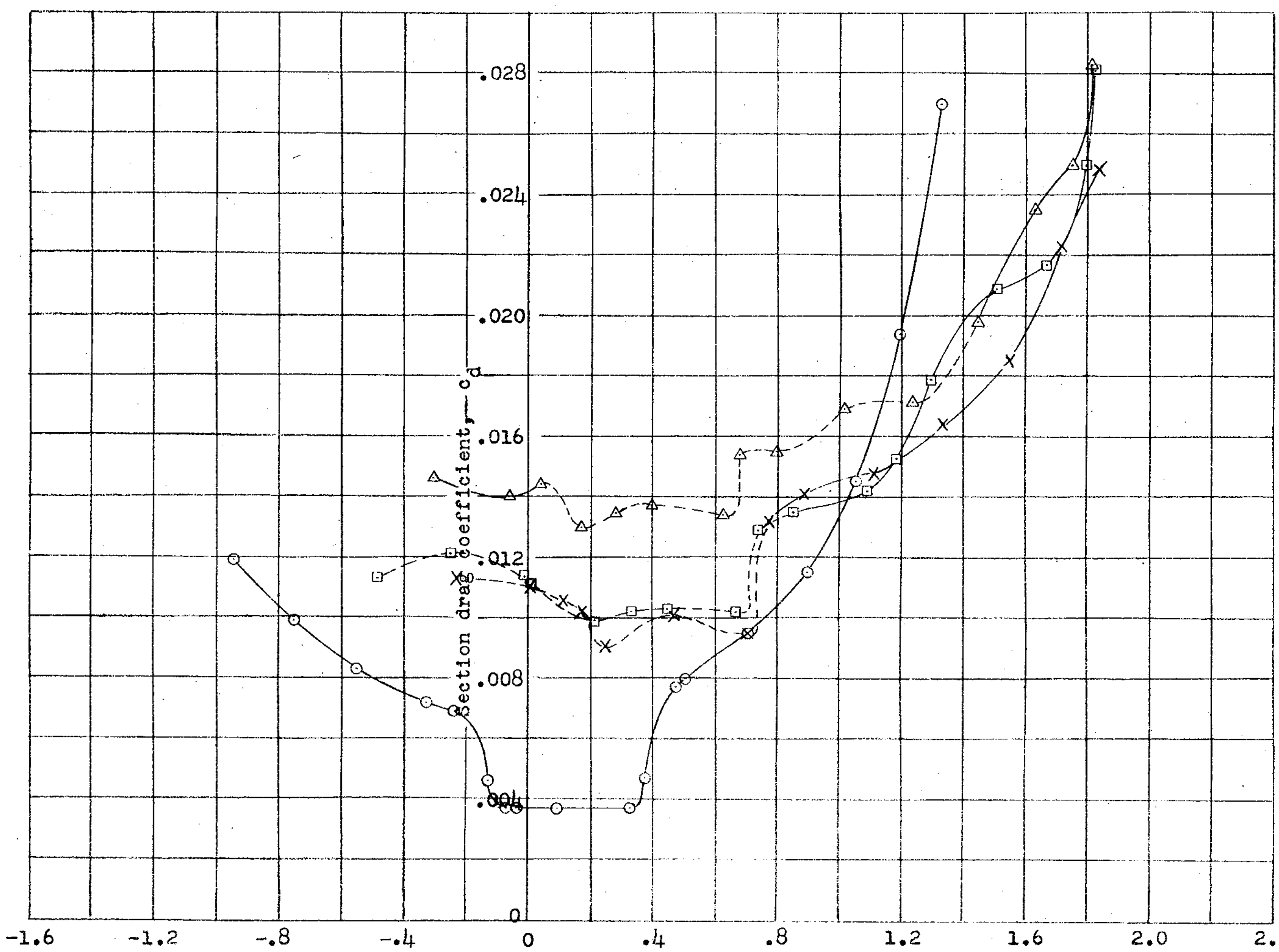

Figure 14.- Drag characteristics with original top and bottom slot cover plates on.

Bell Aircraft Corporation Model
XP-63 wing, NACA 66,2-116 a = 0.6 section
24-inch chord model with slotted flap
Test no. TDT 203
$R = 6 \times 10^6$ (approx.)

No. 2 Condition: Bottom slot cover plate off (Original top plate on.)

Flap angle	Hinge location
⊙ $\delta_f = 0°$	Upper
△ $\delta_f = 15°$	do
⊡ $\delta_f = 15°$	Middle

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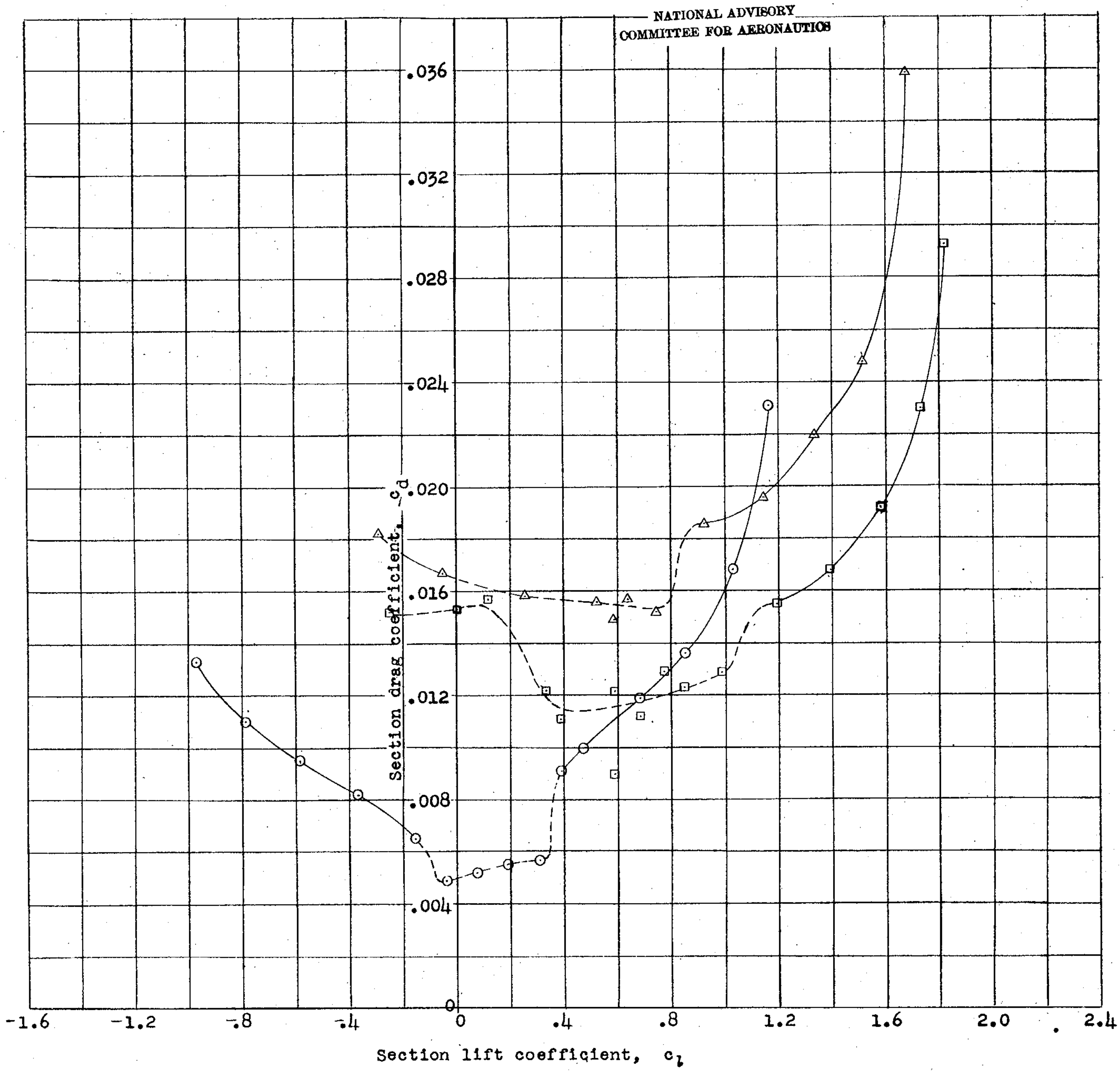

Figure 15.- Drag characteristics with bottom slot cover plate off (original top plate on.)

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Bell Aircraft Corporation Model
XP-63 wing, NACA 66,2-116 a = 0.6 section
24-inch chord model with slotted flap
Test no. TDT 203
$R = 6 \times 10^6$ (approx.)

No. 3 Condition: Partial bottom slot cover plate on (5/8-inch shorter than original.)
Original top cover plate on.

Flap angle	Hinge location
⊙ $\delta_f = 0^\circ$	Upper
△ $\delta_f = 15^\circ$	do

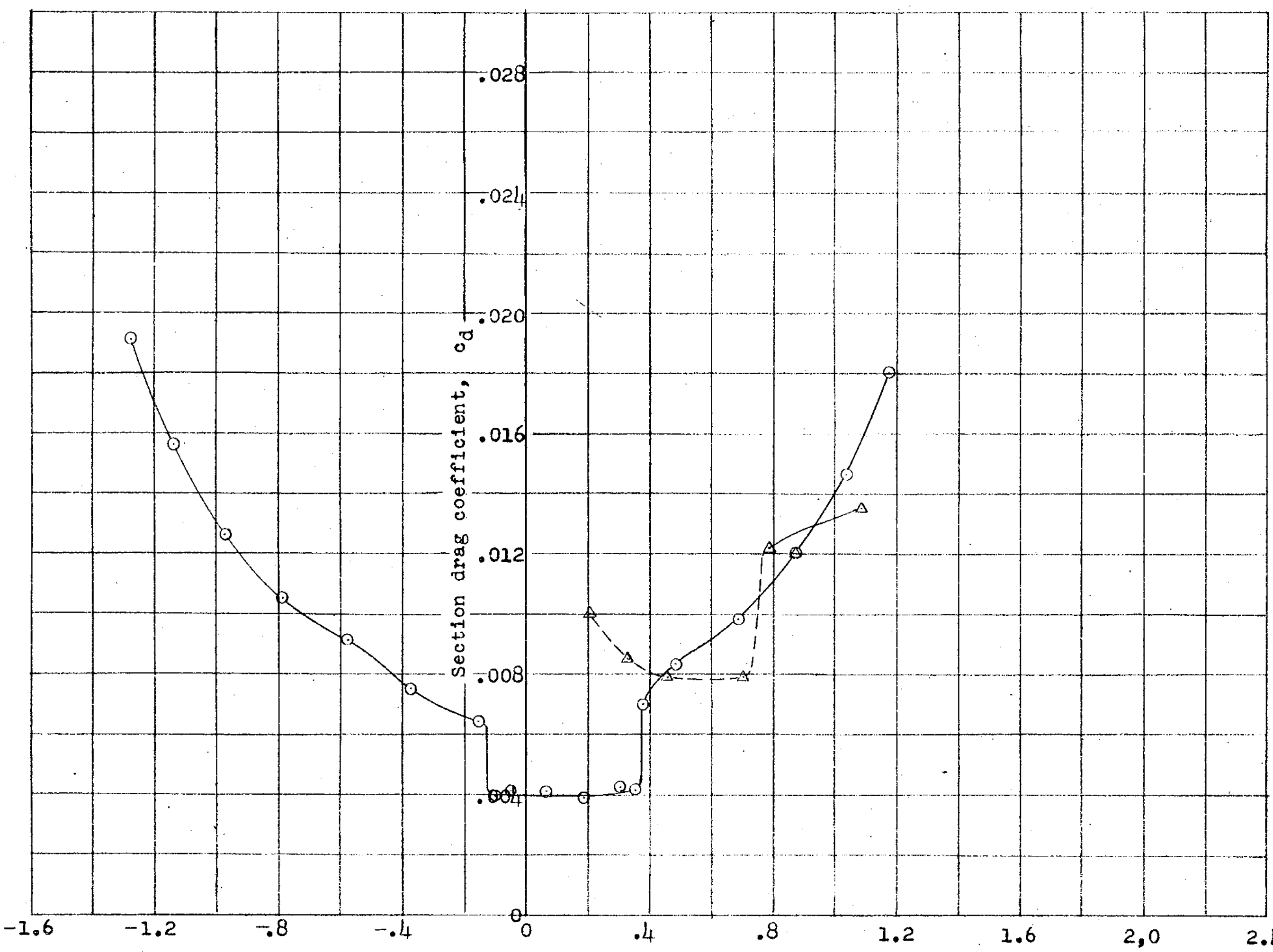

Figure 16.- Drag characteristics with partial bottom cover plate on (original top plate on.)